PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in Fluid Treating Method and Apparatus

I, ABE HERSHLER, a citizen of the United States of America, of 138-10 Franklin Avenue, Flushing, County of Queens, State of New York, United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement: —

The invention relates to methods and apparatus for the treatment of fluids; and it relates more particularly to a novel method and apparatus for the stirring and agitation of liquids wherein a plurality of separate movable magnetic or magnetisable elements are immersed in or distributed throughout the fluid to be mixed and then are subjected to a magnetic field varying with time in direction and intensity to impart individual motions to these elements.

The stirring or agitation of liquids or powders in a container has long been conventionally effected by mechanical means, such as immersed stirring paddles of the rotary or oscillating types, immersed stationary paddles with the container rotating or oscillating, and both the immersed paddles and the container rotating and oscillating relative to each other. Stirring has been effected, particularly where it is desired to maintain the contained fluid completely sealed which eliminates the possibility of using a mechanical linkage, by oscillating the container relative to its contents, the inertial force of the contents effecting the agitation thereof. A magnetic linkage between a stirring element and a drive has also been resorted to. In the latter case, the stirring element, a permanent magnet commonly in the shape of a rod, is located in the container and is magnetically coupled to an external magnet rotated by an electric motor to correspondingly rotate the stirrer magnet.

The conventional fluid stirring and agitation procedures, as typified by those described above, possess many drawbacks and disadvantages. The stirring action is of a gross securing nature since the motive force or drive is periodic and is transmitted to the fluid in an over-all manner. While turbulence and non-streamline flow may occasionally occur, this is very limited both in duration and space and thus contributes little to the over-all agitation. The general character of the fluid movement is non-turbulent and streamlined, as exemplified by a single vortex or rotary flow, which is highly inefficient for dispersing or dissolving purposes. While the agitation of large batches of liquids may be adequately accomplished by the conventional procedures, the stirring of very small masses of liquids or powders in small volume containers, as typified by microstirring, is not practical with the conventional stirrers by reason of the large minimum dimensions of these stirrers, and the drive linkages which necessitate the use of oscillator or shaker type of mechanisms with their consequent drawbacks.

It is thus a principal object of the present invention to provide a novel method and apparatus for the treatment of fluids.

Another object of the present invention is to provide a novel method and apparatus for the stirring and agitation of fluids such as liquids, powders and other fluid materials.

Still another object of the present invention is to provide a novel method and apparatus for stirring and agitating a fluid substantially uniformly throughout the volume thereof.

A further object of the present invention is to provide a novel method and apparatus for uniformly stirring and agitating a fluid in a container independently of the configuration of the container.

Still a further object of the present invention is to provide a novel method and apparatus for stirring and agitating minute quantities of fluid materials.

Still another object of the present invention

is to provide a novel method and apparatus of the above nature characterized by its versatility, flexibility, high efficiency, simplicity, low cost, and applicability of the fluids of various physical properties.

Another object of the present invention is to provide a novel method and apparatus for stirring and agitating preselected regions of a fluid.

The above and further objects of the present invention will become apparent from a reading of the following description taken in conjunction with the accompanying drawings which illustrate preferred forms of the present apparatus wherein:

Figure 1 is a vertical sectional view of a preferred embodiment of the present invention;

Figure 2 is a vertical sectional view of another embodiment of the present invention;

Figure 3 is a vertical sectional view of still another embodiment of the present invention;

Figure 4 is a vertical sectional view of a further embodiment of the present invention;

Figure 5 is a vertical sectional view of still a further embodiment of the present invention; and

Figure 6 is a vertical sectional view of another embodiment of the present invention.

The stirring or agitation of a fluid throughout the volume thereof may be efficiently effected by subjecting a plurality of permanent magnets dispersed or distributed in the fluid to a magnetic field rapidly varying in direction. Each of the magnets exposed to the direction varying magnetic field has a motion imparted thereto which effects the agitation and stirring of the fluid in the ambient region. Thus agitation is independently and directly imparted to the spatially distributed regions in the fluid volume as contrasted to the conventional stirring procedures where motion is transmitted to the fluid from the stirrer element or mechanism by way of the fluid itself. In the process a thorough agitation is effected uniformly throughout the fluid volume, and there is a relatively high relative movement of adjacent fluids, a mechanism highly desired in stirring operations, as distinguished from the conventional practice where such relative movement is radically less. The apparatus required to effect the present stirring action is of the utmost simplicity, consisting of a plurality of small permanent magnet elements capable of being dispersed or suspended throughout the fluid volume being treated and a solenoid, with or without a core of magnetic material, connected to a source of alternating current.

The features and advantages of the present stirring and agitating method are numerous. The process may be effectively applied to fluids in containers varying in size and configuration practically without limit, from millimeter bore tubes to large vats and tanks of any shape whatsoever, as well as in containers defined by biologic organs or ducts. Furthermore, the stirring action may be directed to preselected regions of a given volume by simply focussing and locating the direction varying magnetic field by the use of magnetic shims, directors, and/or cores and by the shape and location of the solenoids. For example, a single defined layer or a plurality of separate layers, or a concentrated region in a fluid volume may be selectively stirred. Moreover, the intensity of agitation throughout the fluid volume or the selected regions may be simply controlled by adjusting the parameters of the magnetic field, such as its intensity, frequency and waveform. By reason of the absence of any mechanical coupling between the stirring element defining permanent magnets and the means for producing the alternating magnetic field, the stirring procedure may be effected in completely closed and sealed vessels which may be under high vacuum or high pressure conditioning, under varying temperature conditions, and under sterile environments. In addition, highly combustible and explosive fluids may be safely treated since there is no sparking or ignition or impact hazard, per se. The present method is highly versatile and applicable to fluids of a wide range of physical properties such as liquids of various viscosities as exemplified by alcohol and glycerine. The present apparatus and method is particularly suitable for stirring and agitating minute quantities of fluids where conventional means possess many drawbacks. Examples of such applications is in the agitation of radioactive solutions, biological and medicinal solutions and in microchemical procedures generally. It should also be noted that the present stirring procedure may be readily applied to continuously flowing fluids, through conduits, pipes, or the like.

The stirring and agitation intensity and efficiency of the present process is a function of many parameters. Included among these are the number of permanent magnet elements present per unit volume of the fluid being processed, the size and configuration of the magnet elements as well as their coercive force, the frequency, wave shape, intensity and configuration of the motivating alternating field, and the viscosity and density of the fluid being stirred. The optimum ranges and values of the above parameters are readily ascertainable.

Generally, the greater the desired stirring intensity per unit volume, the greater the number of motive particles or elements and the higher the magnetic field strength. Where the same mass of magnetic elements are employed, as hereinafter limited, the smaller the element the greater the stirring. The minimum size of the permanent magnet elements is that of the single magnetic domains, which vary in size with the permanent magnetic material

between 0.01 and several microns in diameter. The maximum element size depends on the viscosity of the fluid being treated and the strength of the magnetic material. The maximum dimensions of the permanent magnet elements is advantageously between 0.1 micron and 1 centimeter although the upper limit may be considerably extended. The shape of the magnet elements should be non-spherical and advantageously of irregular and non-uniform configuration and preferably in the shape of elongated needles or rods.

The magnet element shape may also be predetermined in which case they are machined, cast, pressed or otherwise formed to the desired configuration which is dictated by the type of magnet element motion sought as well as the type of efficiency of agitation and the material forming the permanent magnet element. Examples of such predetermined shapes are I, X, H, L or the like. Moreover the permanent magnet elements may be coated or otherwise encased in a preferably thin layer of a material inert to the fluid being treated such as a polyolefin, a halogenated polyolefin, for example, polytetrafluoroethylene, glass, rubber, a silicone or the like.

The coercive force of the magnet elements should be as large as possible and should advantageously exceed $H_c=50$ oersteds. A material which is highly satisfactory is barium ferrite, both oriented and non-oriented. Irregularly shaped particles of suitable size and configuration for use as magnet elements may be obtained by crushing a barium ferrite permanent magnet and grinding the particles in a mill to the desired size. The mechanism for producing the alternating magnetic field may be a hollow solenoid of convenient shape and may be provided with a magnetic core to concentrate the magnetic field in the desired regions, as will be hereinafter set forth. The ampere turns or magnetic field intensity may be adjusted to best suit the conditions, the higher the liquid viscosity, the higher the desired magnetic field intensity. The frequency should be in a range to impart a suitable motion to the magnet elements, for example from about 1 to 100,000 cycles per second although 60 cycles per second may be used to great advantage because of its ready availability.

The alternating magnetic field imparts a random complex motion to the magnet elements. The magnetic moments impart rotation and spin to each of the magnetic elements which tend to align themselves in proper orientation with the magnetic field and the non-uniformity of the magnetic field imparts a translation motion thereto. The resulting magnet element motion includes axial oscillations due to the inability of the magnetic elements to rotate a full 180° with each reversal of the magnetic field. An additional spinning is due to the existence of torques, resulting from the lack of alignment of the alternating magnetic field and the magnetic axis of the magnet elements while in axial motion. Furthermore, the alternating magnetic field and the magnet field of the magnet elements promote the uniform dispersion or suspension of the magnet elements in the alternating magnetic field permeated fluid.

As aforesaid, the container or receptacle holding the fluid may be of any desired shape and should be formed of a non-magnetic material such as glass, synthetic organic plastics for example, tetrafluoroethylene, polyethylene, polypropylene and the like, ceramics, non-magnetic metals such as certain of the stainless steels, organic tissue, etc. Where the means for inducing the magnetic field includes a magnetic core it should be of the laminated or powdered type and preferably of a low Steinmetz coefficient to minimize eddy current and hysteresis losses. Following the stirring of the fluid, the magnet elements may easily be separated therefrom by halting the alternating magnetic field and introducing an iron rod or permanent magnet into the fluid which will collect the magnetic elements which agglomerate on the iron rod.

Referring now to Figure 1 of the drawings, which illustrates a preferred embodiment of the present invention, the reference numeral 10 generally designates an annular shaped solenoid suitably mounted in a horizontal position and connected by way of an adjustable autotransformer 11 or other current control means and a switch S to a source of alternating current. The size, location and shape of the solenoid 10, and the magnitude and frequency of the current supplied as well as the current in the solenoid 10 are as above set forth. Disposed on the solenoid 10 is a support plate 12 formed of a non-magnetic material and container or receptacle 13 likewise of a non-magnetic material, for example glass or polytetrafluoroethylene, rests on the support plate 12. Receptacle 13 contains a fluid such as a liquid F in which is located or dispersed a plurality of permanent magnet elements 14 of the nature earlier described. The liquid F, which it is desired to stir and agitate, may contain a soluble or dispersible material for dissolving or dispersing in the liquid, or the liquid F may be stirred for other purposes.

Upon closing of the switch S the solenoid 10 is energized to establish an alternating magnetic field which permeates the liquid F and imparts a motion to each of the magnet elements 14 of the character earlier set forth, the moving magnet elements, in turn, stirring and agitating the liquid F throughout the volume thereof. It is important to note that in the absence of the alternating magnetic field the magnet elements will usually agglomerate or clump together into a ball or mass at the bottom of the vessel. This clumping

or balling action is a result of the mutual attraction of the permanent magnet particles which draws together as a coherent mass. However upon the establishment of the proper alternating magnetic field, as aforesaid, the ball or mass literally explodes into the discrete separated magnet elements which maintain their separated discrete identities as long as the alternating magnetic field is present. Upon discontinuance of the alternating magnetic field the magnet elements tend to clump and ball together thereby facilitating their removal from the fluid. Thus the magnet elements are automatically distributed in the fluid by the motivating alternating magnetic field.

The intensity of the stirring and agitating action may be varied by adjusting the autotransformer 11 and hence the magnetic field intensity. It should be noted that the receptacle 13 may be of any configuration, may be open, or closed and sealed, may be heated and may be subjected to any ambient conditions. If it is desired to effect a stirring of greater intensity in a selected region of the liquid F, a magnetic shim or magnetic field focussing or concentrating member, for example a soft iron rod, or a permanent magnet, may be brought into the vicinity of the aforesaid region to thereby increase the magnetic field intensity there and the consequent stirring activity. Upon the completion of the stirring operation, the switch S is open, halting the motion of the magnet elements 14, and a soft iron rod or permanent magnet is immersed in the liquid F to collect the magnet elements 14 which agglomerate thereon.

In accordance with a specific example of the present process employing the above apparatus, it being understood that the example is given merely by way of illustration and is not intended to limit the scope of the present invention, the solenoid 10 was of annular shape having a height of 2 inches, an inner diameter of 1 1/2 inches and an outer diameter of 3 inches and contained 500 turns of wire. The solenoid was connected to a source of 60 cycles alternating current and the current therein was about 10 amperes. Where the liquid to be stirred was water or alcohol, 100 magnet elements 14 were distributed in the liquid F, the magnet elements 14 being defined by irregularly shaped barium ferrite permanent magnet elements having average diameters of 0.005 inches and where the liquid F was glycerine, the same number of magnet elements 14 were employed but their average diameter was about 0.100 inch. In each case the stirring action was virtually instantaneous and at high amplitudes, easily produced frothing and an air-liquid suspension. In the above example, the volume of the liquid F was about 50 milliliters in a 100 milliliter beaker.

As seen in Figure 2 of the drawing, the receptacle for the liquid F may be of various shapes, may be located in different positions relative to the solenoid 10 and a plurality of receptacles may be subjected to the alternating magnetic field of a single solenoid. Specifically, the receptacles include a closed container in the form of a stoppered bottle 16 projecting through the opening in the solenoid 10, a shallow beaker 17 located above the level of the solenoid 10 and a test tube 18 registering with the solenoid opening. Each of the receptacles 16, 17 and 18 contain a liquid F through which are dispersed magnet elements 14 in number and size depending upon the viscosity of the liquid F and the volume thereof and the desired intensity of stirring. In order to concentrate or increase the stirring intensity in the region 19 of the receptacle 16 a magnetic field directing and concentrating member 20 in the form of a soft iron bar is supported in the vicinity of, and aligned with the region 19 to increase the magnetic field intensity there, and consequently the stirring activity. The field concentrating member 20 may assume various shapes and sizes in accordance with the size and configuration of the region of increased stirring activity as may be determined by one skilled in the art.

In Figure 3 of the drawing, there is illustrated a form of apparatus which may be employed for effecting the stirring of selected layers or zones in a liquid. The apparatus comprises a magnetic core or frame member 21 including a bottom cross-piece 22, a pair of upright end legs provided with one or more pairs of opposite legs 24 directed toward each other and having laterally spaced inner ends. Where more than one pair of legs 24 are provided, as illustrated, the pairs are vertically spaced to permit the stirring of vertically separated layers of the liquid F. A solenoid 26 is wound around the cross piece 22 and connected to a source of alternating current as earlier set forth. A receptacle 27, for example, a beaker, contains a liquid consisting of three distinct layers or components A, B, and C and registers with the magnet frame 21, the legs 24 being aligned and colevel with the components A and C where stirring is desired independent of the intervening component B. Magnet elements 14 are dispersed throughout the layers A and C and the stirring motion imparted thereto by the alternating magnetic field established between the legs 24 of each pair and concentrated in the respective layers A and C. The intermediate layer B is substantially free of the magnet elements 14 and is permeated by a relatively weak and substantially negligible alternating magnetic field. It should be noted that where only one layer section of a liquid is to be stirred only one pair of legs 24 is provided. The legs 24 are preferably as wide as the transverse dimension of the

receptacle 29 so that the entire cross sectional area of the fluid at the desired levels is permeated by a strong alternating magnetic field. The magnet core 21 as well as the other magnet cores herein employed are constructed in the well known manner to minimize eddy current and hysteresis looses and are preferably formed of high magnetic permeable materials.

In Figure 4 of the drawing, there is illustrated another form of apparatus which is suitable for the zone or layer stirring of a liquid. A test tube 28 containing a liquid F registers with the opening of an annular solenoid 10 connected to an alternating current source. A collar 29 of soft iron or other magnetic material encircles the test tube 28 at a predetermined level and concentrates the alternating magnetic field produced by the solenoid 10 at a corresponding level in the liquid F in the test tube 28. Magnet elements 14 are suspended and motivated in the liquid F at the level of the collar 29 to stir the liquid in the corresponding region. By varying the relative axial positions of the collar 29 and the test tube 28 the stirring level may be accordingly adjusted.

Another form of apparatus which is suitable for use with deep vessels is illustrated in Figure 5 of the drawing. The apparatus includes a magnetic core member base 32 comprising a cross member base 33 provided with upright end legs 34 terminating in inwardly directed arms 36, and a medially located, upright bar 37 having a concavity formed in its upper face. A solenoid 38 is wound about the bar 37 and is connected to an alternating current source to establish an alternating substantially vertical magnetic field extending from the level of the core arms 36 to the bar 37. A vessel 39 in the form of a test tube extends vertically from between the arms 26 to the bar 37 and contains a liquid having the permanent magnet elements dispersed therethrough. Stirring of the liquid is effected by the magnet elements motivated by the aforesaid alternating magnetic field which permeates the liquid in the vessel 39.

Stirring and agitation of a continuously flowing liquid may be effected by the apparatus illustrated in Figure 6 of the drawing. The apparatus comprises a pipe or conduit 40 formed of a non-magnetic material and a solenoid 41 registering with a section of the conduit 40 and connected to a source of alternating current. The stirring region 42 is delineated by a pair of axially spaced perforated plates 43 extending across the conduit 40 at opposite sides of the solenoid 41. A plurality of magnet elements are located in the region 42 and suspended in the liquid therein and are larger than the openings in the plates 43 to prevent their escape from the region 42. The alternating magnetic field established by the solenoid 41 through the region 42 motivates the magnetic elements to stir and agitate the liquid therein. It should be noted that the conduit may be of any desired configuration and follow any desired path and the region 43 may extend for any desired length of the conduit and elongated solenoids or a plurality thereof may be employed. Furthermore, the cross section of the conduit 40 may vary along its length, as desired. Moreover, instead of employing one or more solenoids 41 wound about the conduit 40 one or more magnetic yokes may be substituted therefor of the type illustrated in Figure 3. Each yoke may be provided with only one pair of legs 24 and the conduit 40 is located between and extends through the space delineated by the confronting yoke legs 24. The cooperating solenoids 26 are connected to sources of alternating current, as aforesaid.

It should be noted that although the various embodiments of the present invention have been directed to the stirring and agitation of liquids, they are applicable to other fluid materials such as powders or the like.

While there have been described and illustrated preferred embodiments of the present invention, it is apparent that numerous alterations, omissions and additions may be made without departing from the scope thereof as defined in the appended claims.

WHAT I CLAIM IS:—

1. The method of treating a material characterized by dispersing a plurality of magnet elements having a coercive force exceeding 50 oersteds in a fluid and subjecting said magnet elements to a magnetic field periodically varying with time in direction and intensity to maintain said magnet elements in spaced relationship and impart motion thereto.

2. The method according to claim 1 wherein said magnet elements are permanent magnets.

3. The method according to any of claims 1 and 2 wherein said magnet elements are of non-spherical configuration.

4. The method of claim 1 wherein said fluid is a liquid.

5. The method of claim 1 wherein said magnetic field varies sinusoidally with time.

6. The method according to any of the preceding claims characterized by the maximum dimensions of said magnet elements being between 0.1 microns and 1 centimeter.

7. The method according to any of the preceding claims characterized by said magnet elements each containing at least one magnetic domain.

8. The method according to any of the preceding claims characterized by said magnetic field alternating at a frequency between 1 and 100,000 cycles per second.

9. The method according to any of the preceding claims characterized by said magnetic field being generated by an electromagnet of at least 1 ampere turn/meter.

10. The method according to any of the preceding claims characterized by said magnetic field being concentrated in a predetermined area of said liquid.

11. The method according to any of the preceding claims characterized by said fluid flowing through said magnetic field while said permanent magnet elements remain therein.

12. An apparatus for treating a material characterized by a container or conduit for holding said fluid, a plurality of magnet elements having a coercive force exceeding 50 oersteds located in said fluid and means for establishing an intensity varying and direction alternating magnetic field through said fluid to maintain said magnet elements in mutual spaced relationship and impart rotational and/or translatory motion to said permanent magnet elements.

13. An apparatus according to claim 12 wherein said magnet elements are permanent magnets.

14. An apparatus according to any of claims 12 and 13 wherein said magnet elements are of non-spherical configuration.

15. An apparatus according to any of claims 12 to 13 characterized by said container being formed of a non-magnetic material.

16. An apparatus according to any of claims 12 to 15 characterized by said magnet elements having a maximum dimension between 0.1 micron and 1 centimeter.

17. An apparatus according to any one of claims 12 to 16 characterized by said magnet elements being of irregular configuration.

18. An apparatus according to any one of claims 12 to 17 characterized by said means for establishing said magnetic field including a solenoid connected to a source of alternating current, said container being located in the vicinity of said solenoid.

19. An apparatus according to any of claims 12 to 18 characterized by means of concentrating said alternating magnetic field in a predetermined region of said fluid.

20. An apparatus according to claim 19 characterized by said concentrating means including a member of magnetic material disposed in the vicinity of said predetermined region.

21. An apparatus according to claim 19 characterized by said concentrating means including a collar of magnetic material encircling said container at a predetermined level.

22. The method of agitating a liquid substantially as described herein.

23. An apparatus for stirring a fluid substantially as described herein and as shown in the accompanying drawings.

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1113046 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

Fig.1.

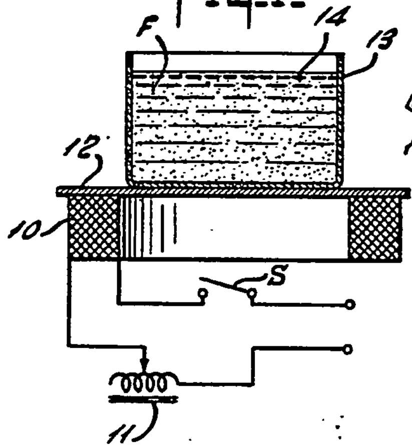


Fig.2.

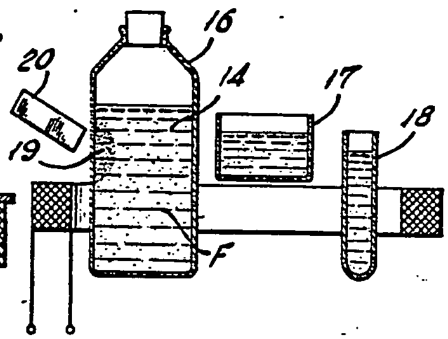


Fig.3.

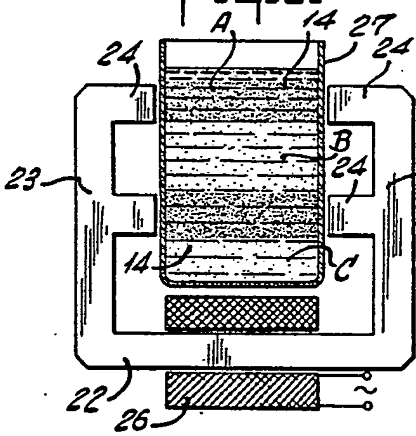


Fig.4.

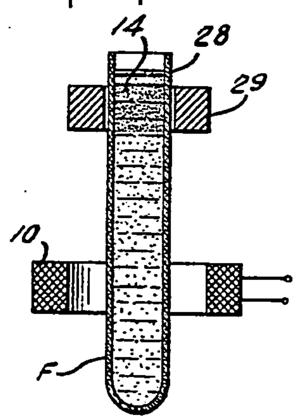
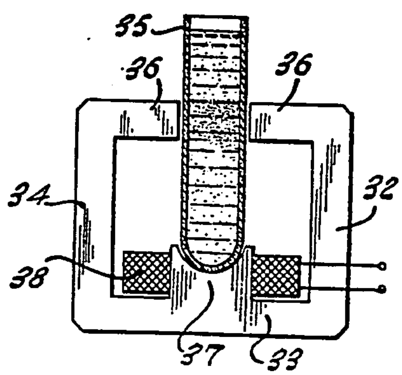


Fig.5.



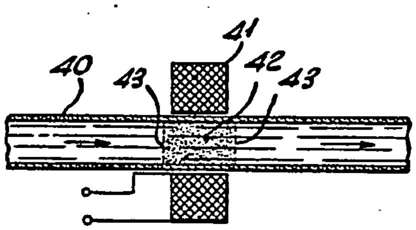


Fig.6.